Direct path fluctuations due to shallow water volume variability

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Introduction

- During two, 24-hour periods of the ECS experiment, Peter Dahl's group deployed a source and two sub-arrays at close range (~500m). The source transmitted short duration pulses at frequencies 4, 8, 16, and 20 kHz. The arrival structure of these pulses sometimes allowed for propagation path discrimination, i.e. the direct water-bourne path was separable from the surface reflected path, which was separable from the bottom reflected path, etc.
- Of interest is the spatial (vertical) coherence of the signal after it has interacted with variable features of the environment. The direct path has only interacted with the water column, and so the coherence provides some measure of the water column variability.
- The goal is to provide numerical modeling results of variety of water column perturbations to determine types of variability needed to affect vertical correlation measure. This will be compared to measured data in the near future.

Model

- Monterey-Miami Parabolic Equation (MMPE) model used to compute propagation. Inputs may include range-dependent sound speed profiles, water-sediment and sediment-basement interfaces, and sediment and basement acoustic characterizations.
- Background sound speed profiles input deterministically, based on single CTD measurement during ASIAEX.
- Sound speed variability based on 3 types of perturbations:
  - Single sinusoidal (IW) perturbation

$$dc \,\square\, B\frac{z}{60}\left(1\text{-}e^{\left(-\frac{(z\text{-}70)}{60}\right)}\right)\cos\left(\frac{2p\,r}{100}\right)$$

  - Combination of multiple (5) sinusoidal perturabtions

$$dc \,\square\, \sum_{i=1}^{5}\frac{B}{i}\frac{z}{60}\left(1\text{-}e^{\left(-\frac{(z\text{-}70)}{60}\right)}\right)\cos\left(\frac{2p\,r}{100/i}\right)$$

  - Small scale, turbulent-like perturbations based on random realization of 2-D variability spectrum

$$W_{dc}(K,M)\,\square\,\left(\Lambda^2K^2+M^2\right)^{-g}$$

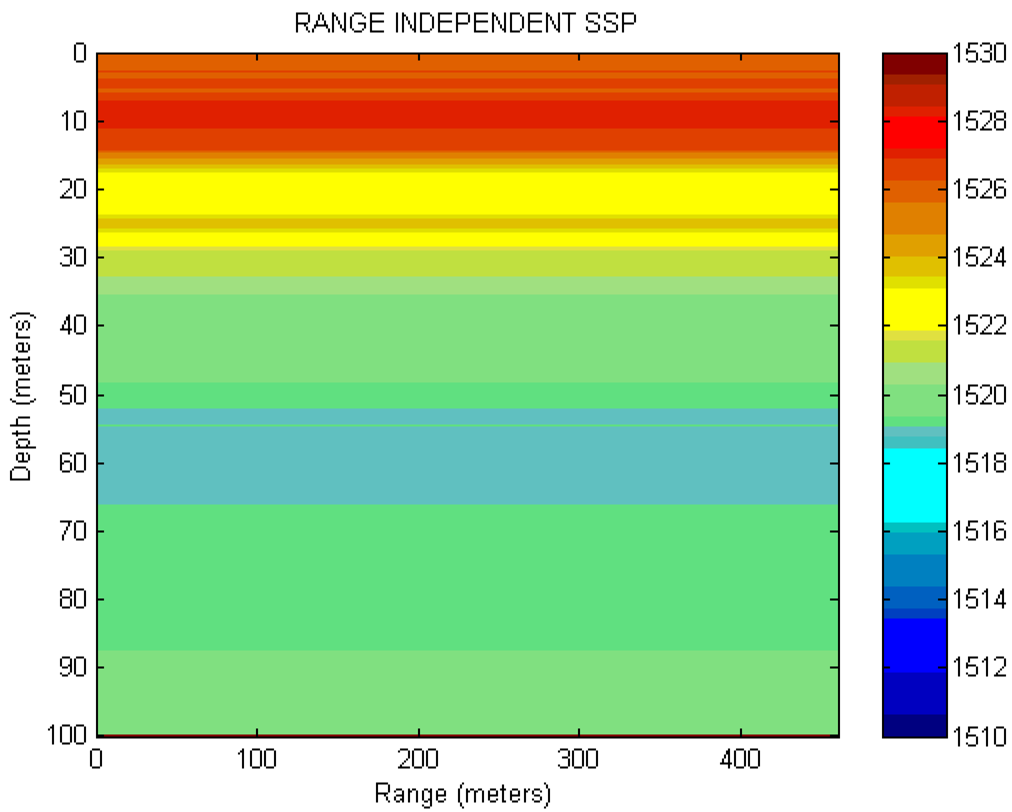
Approach

- Compute broadband arrival time structures based on source at 50m depth. Source transmits frequency spectrum consistent with 2msec CW pulse. Solution stored at range of 460m.

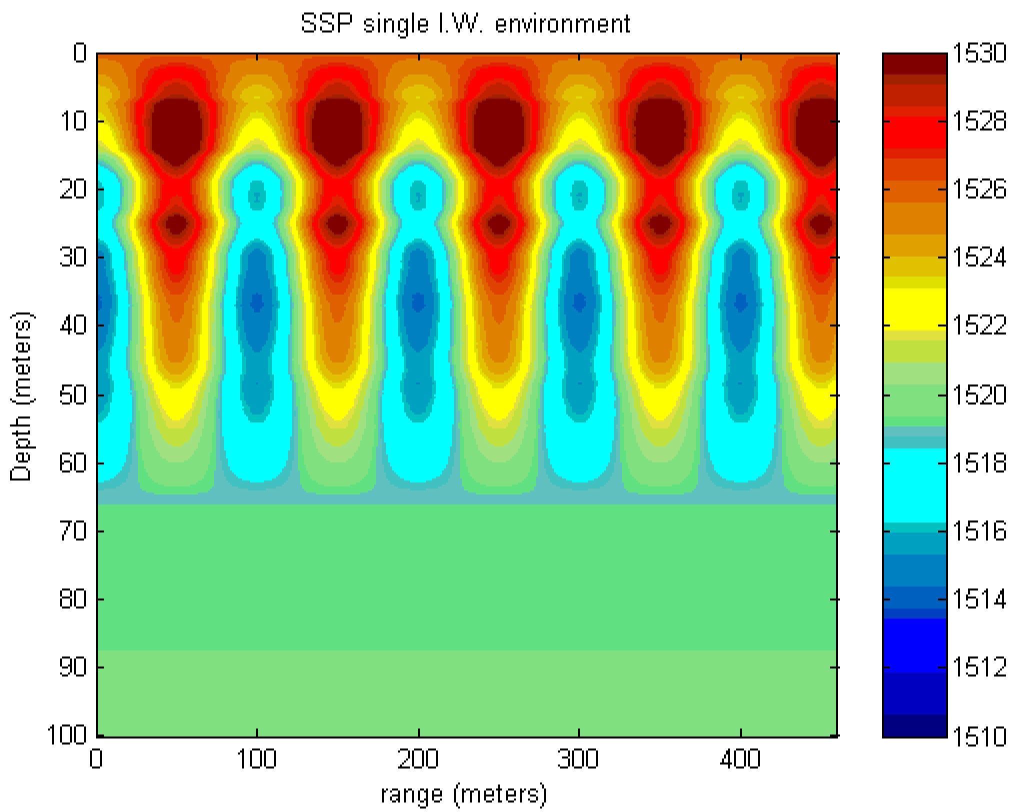
- Arrival structures extracted at depths similar to two sub-arrays used in experiment. Vertical correlations computed over sub-arrays.

- Re-run similar calculations for each perturbation.

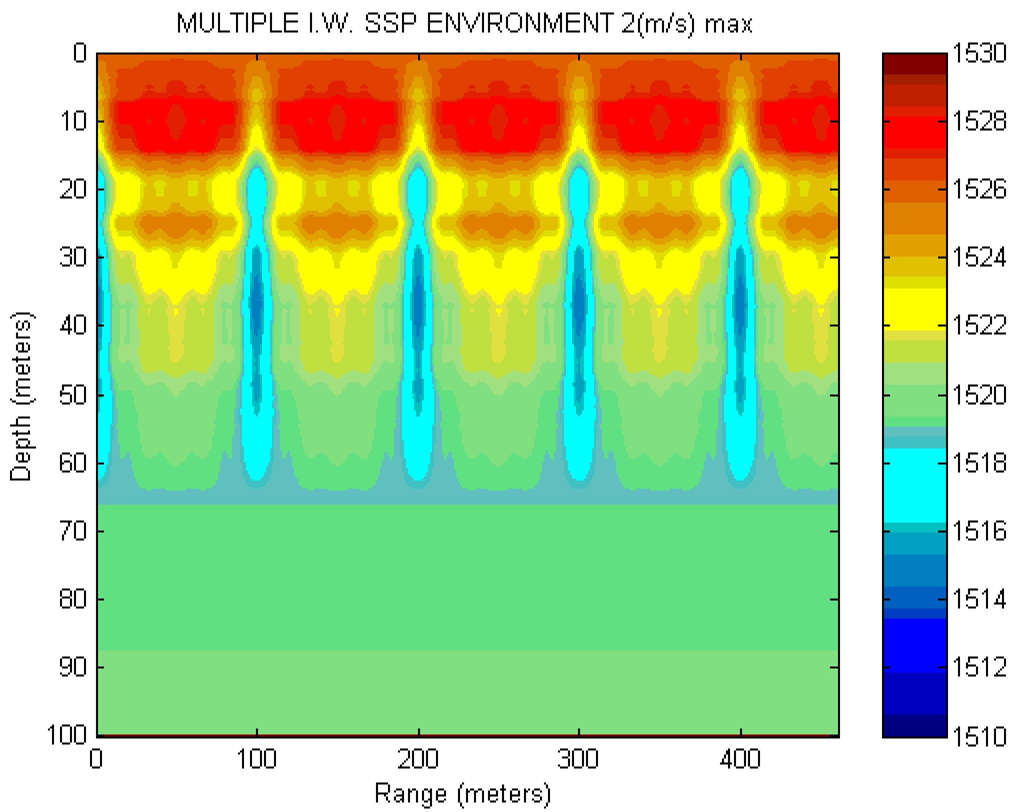
Range - Independent



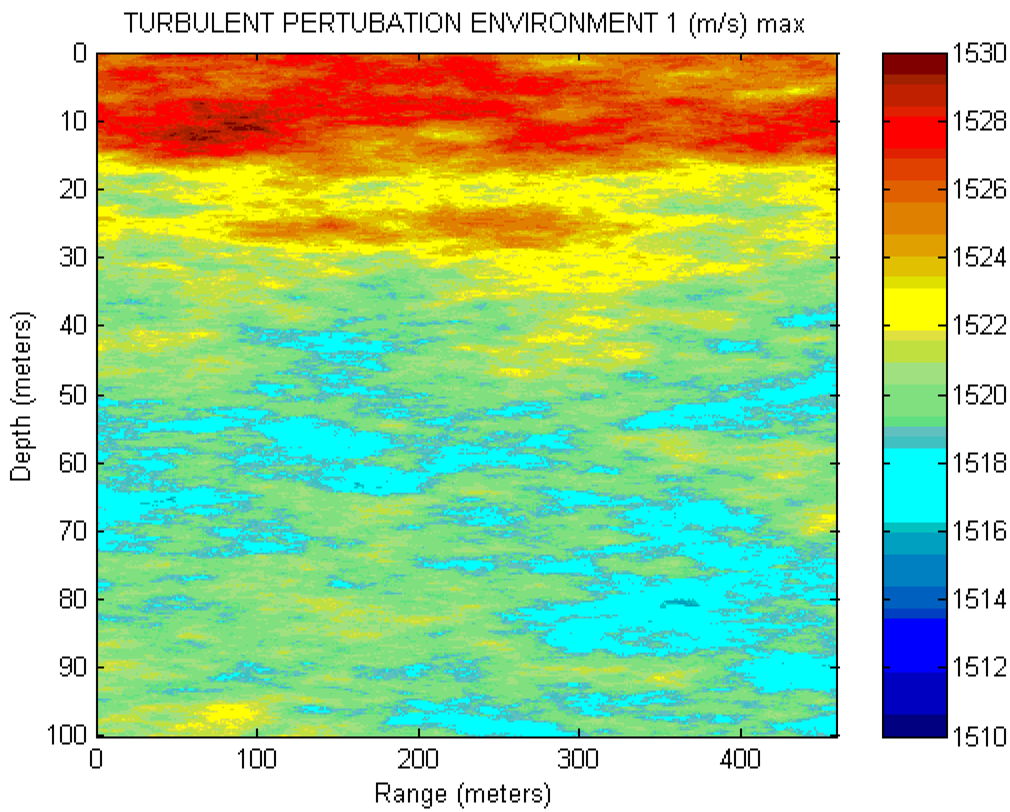
Range-Dependent, Single Sinusoid



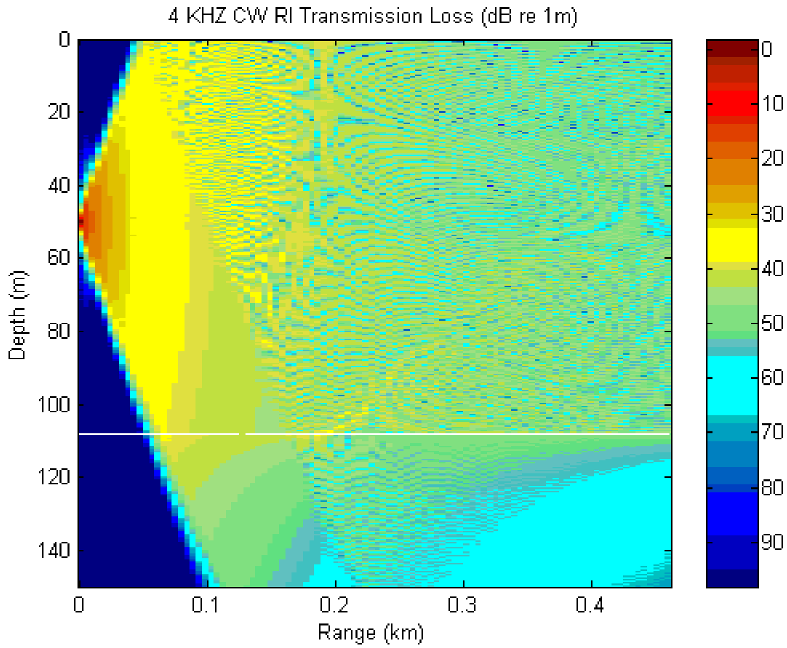
Range-Dependent, Multiple Sinusoids

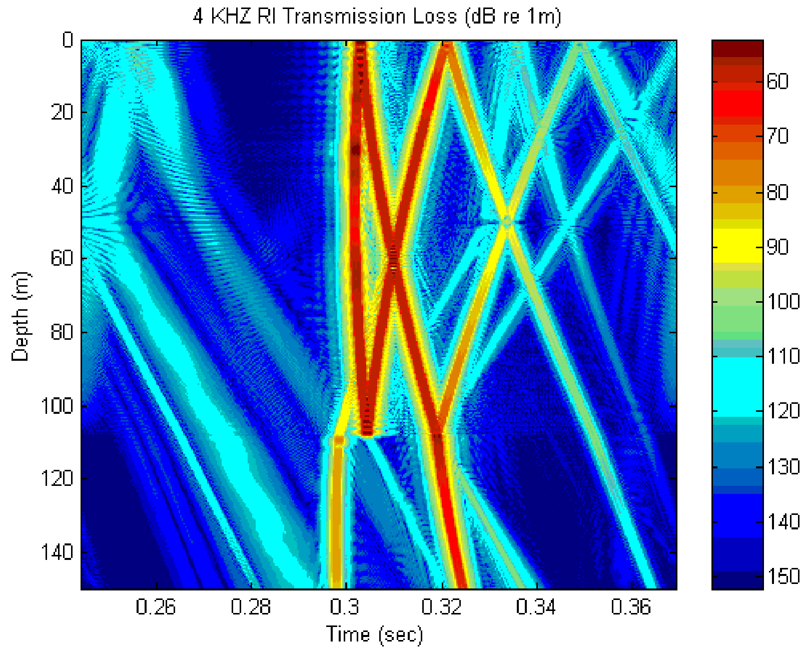


Range-Dependent, Random Perturbations



Range-Independent, TL Plots





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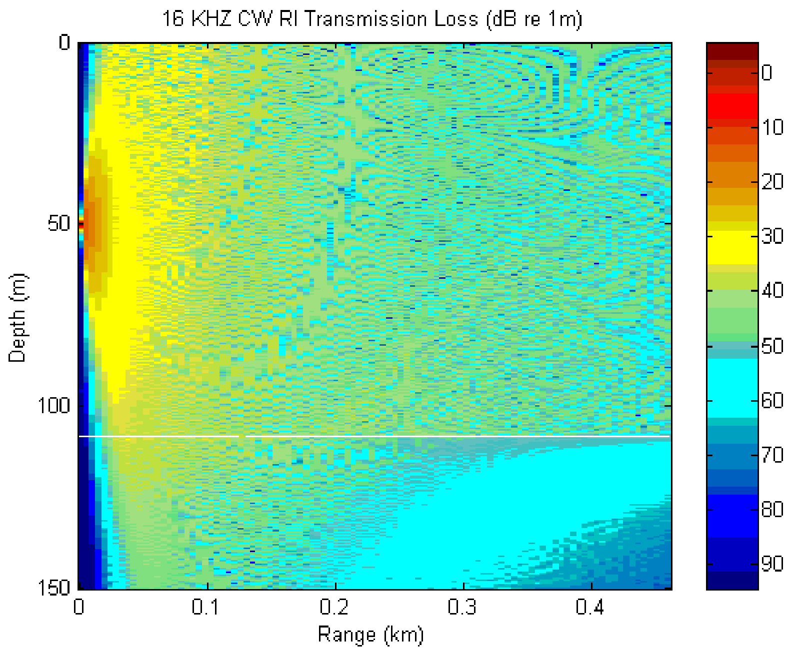
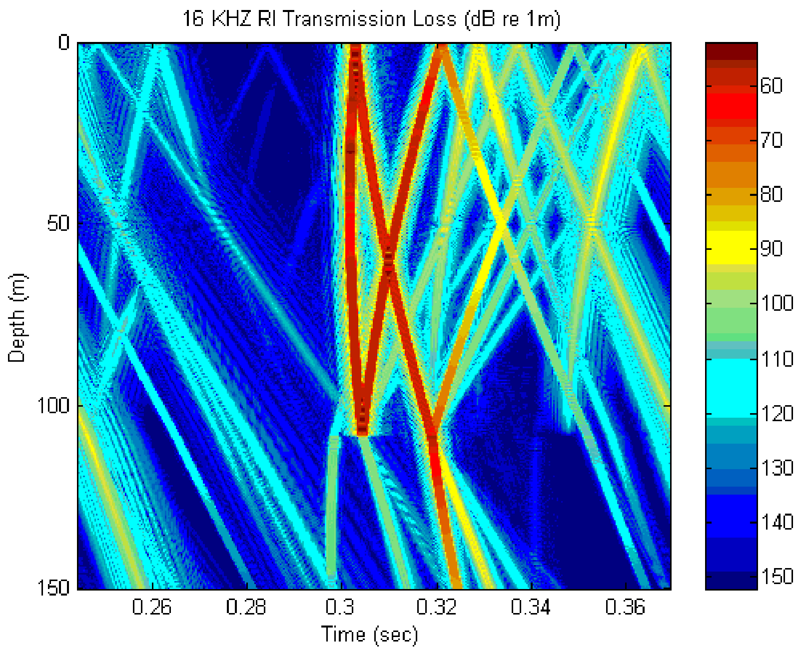
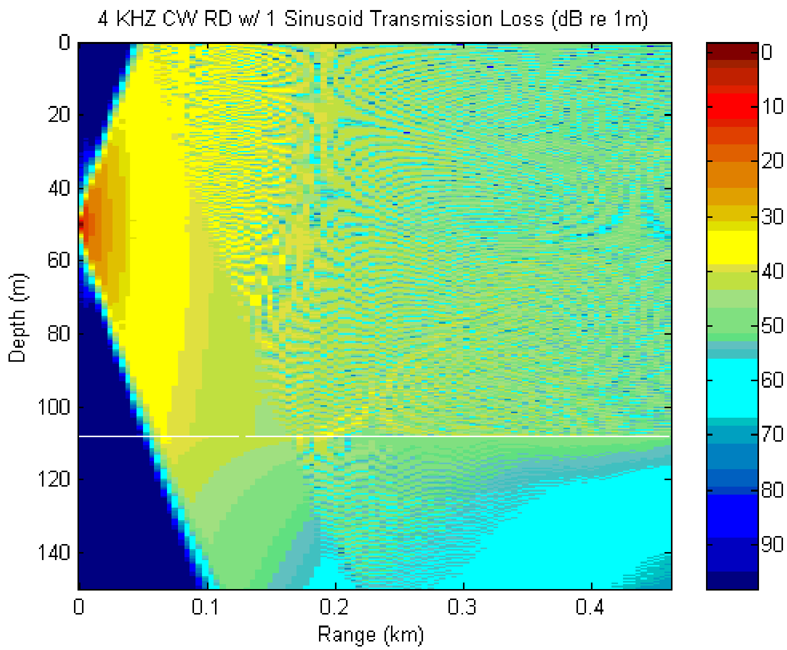
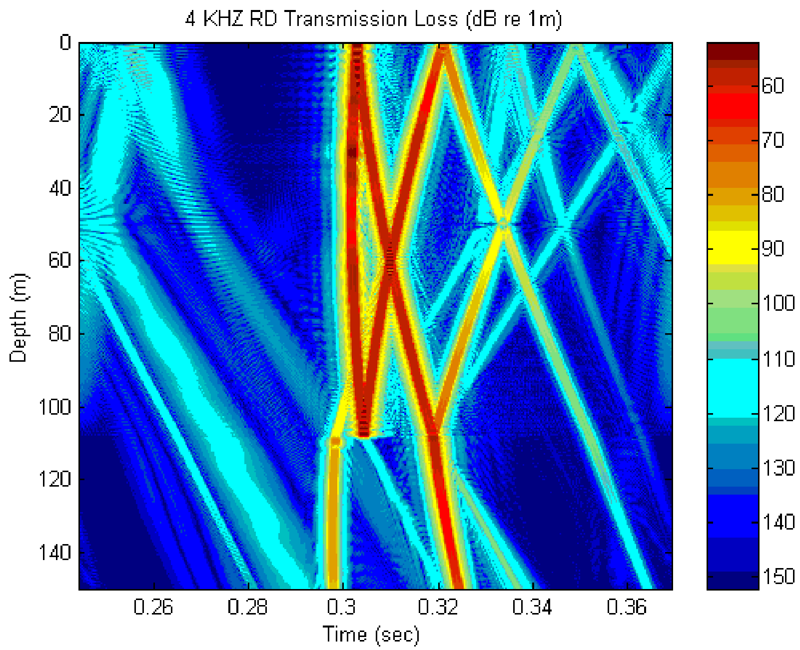




Range-Dependent, Single Sinusoid, TL Plots





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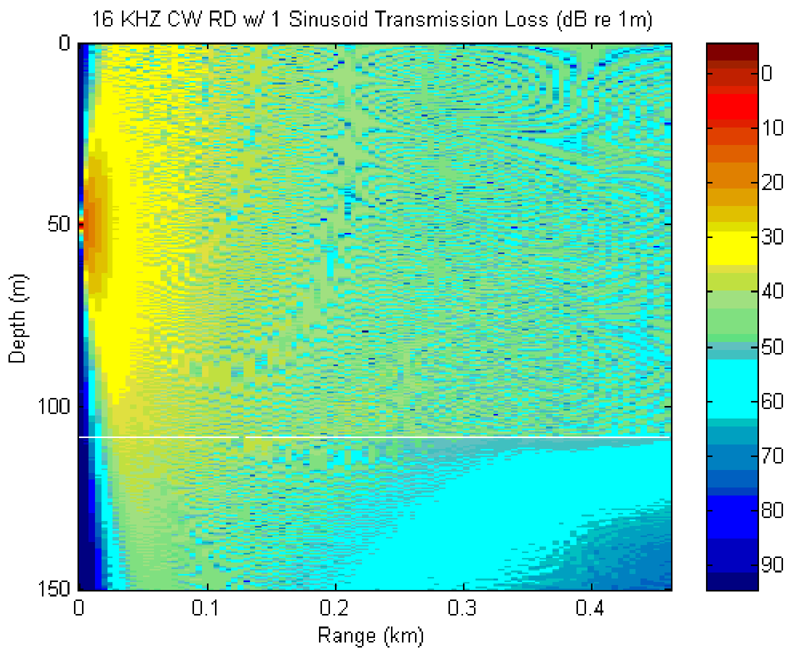
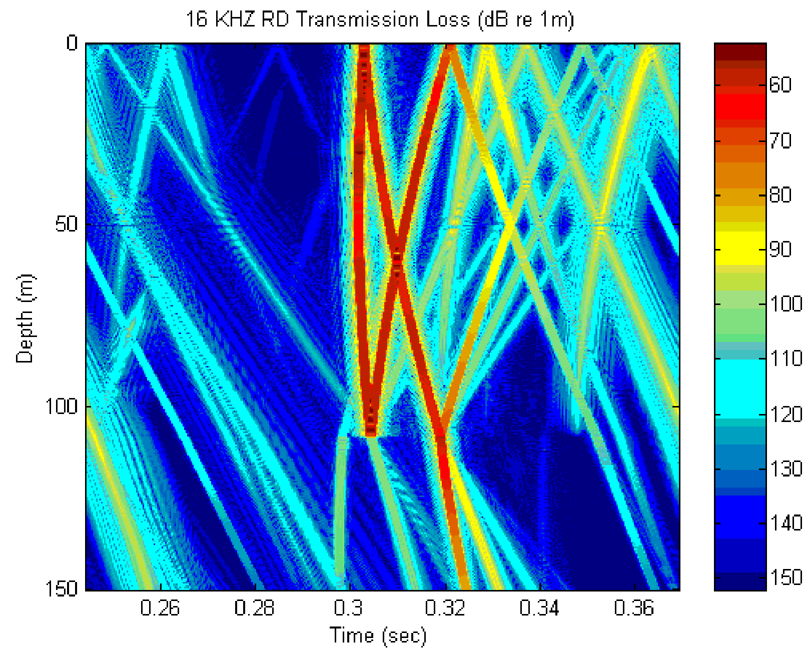
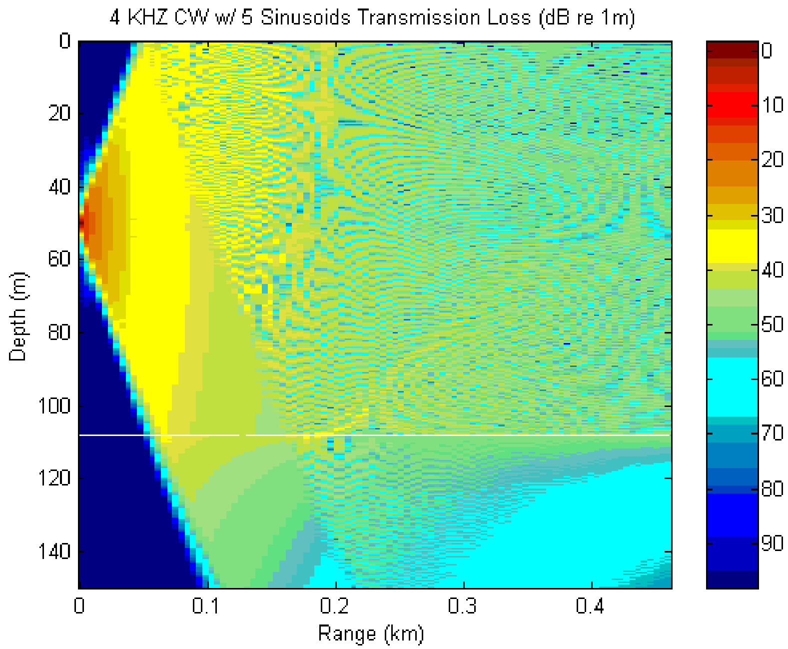
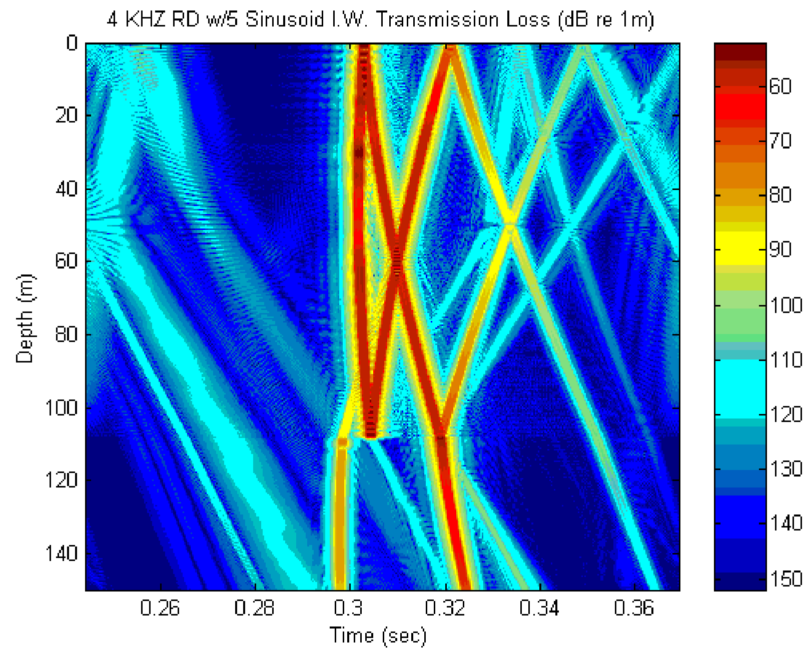




Range-Dependent, Multiple Sinusoids, TL Plots





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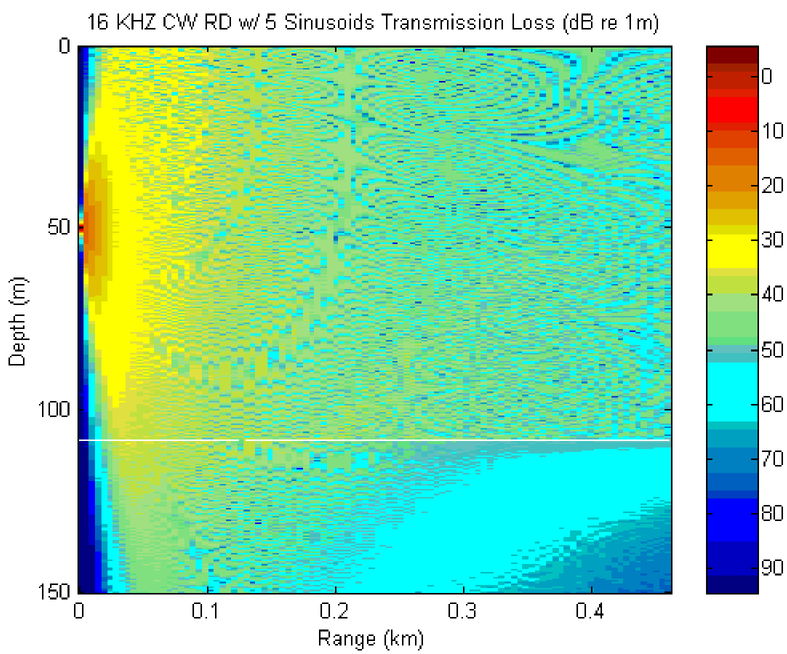
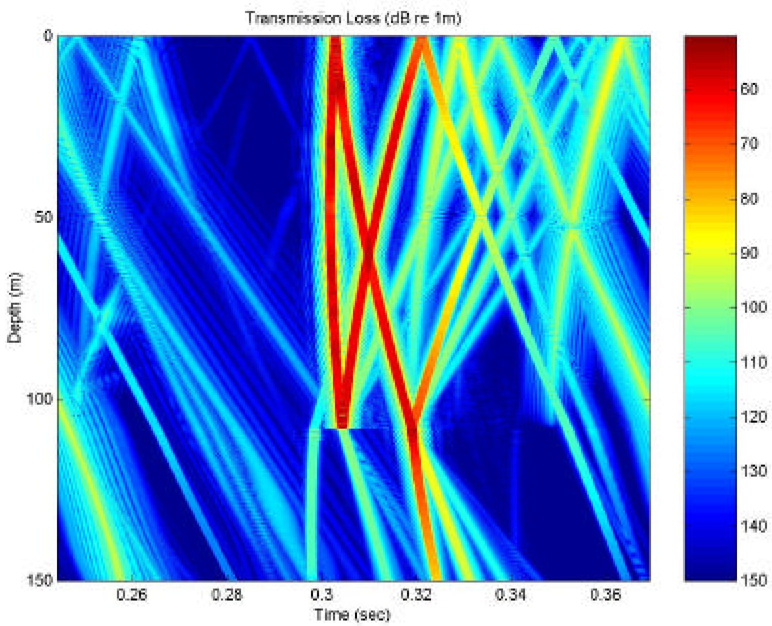
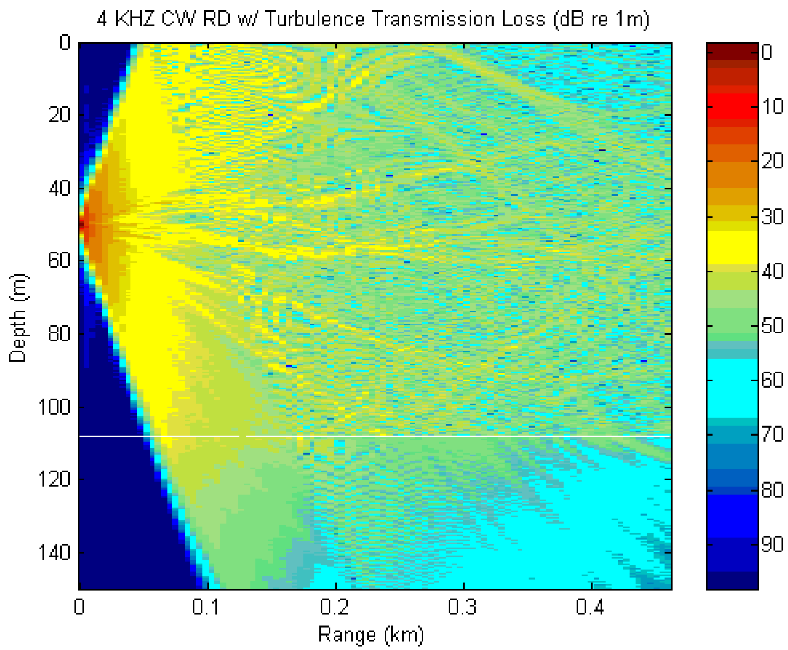
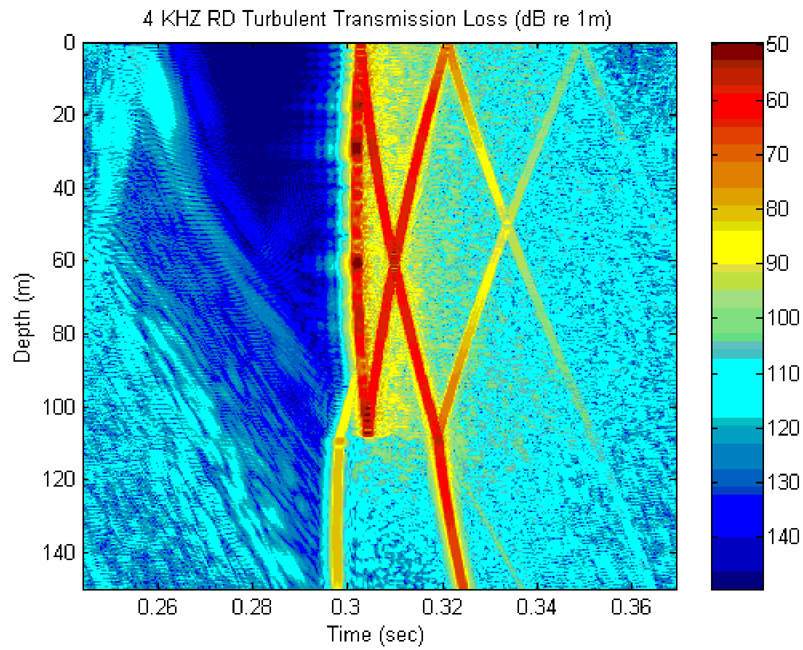




Range-Dependent, Random Perturbations, TL Plots





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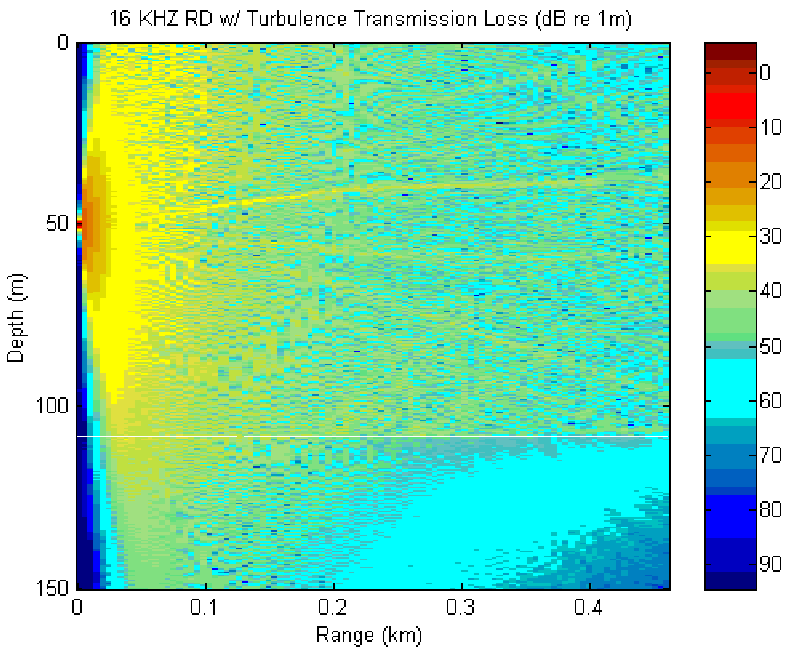
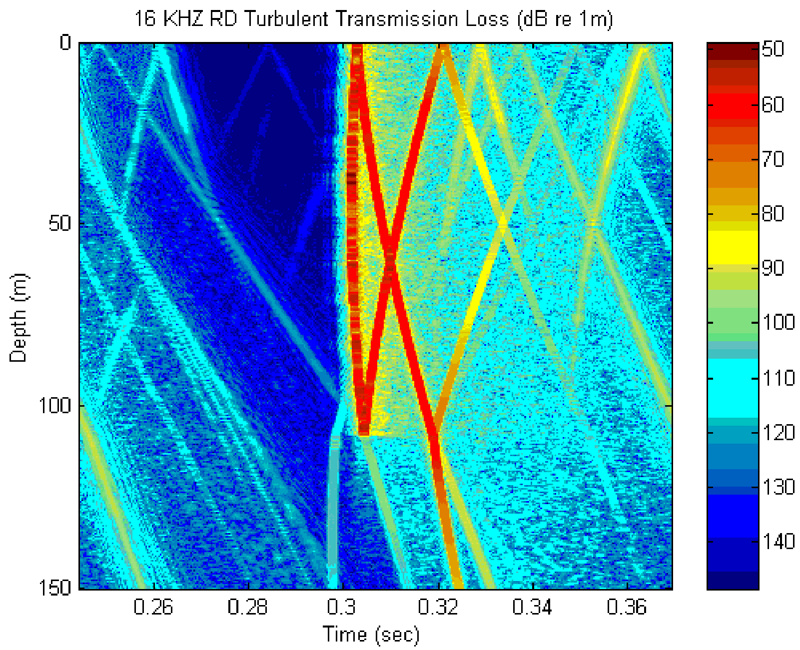
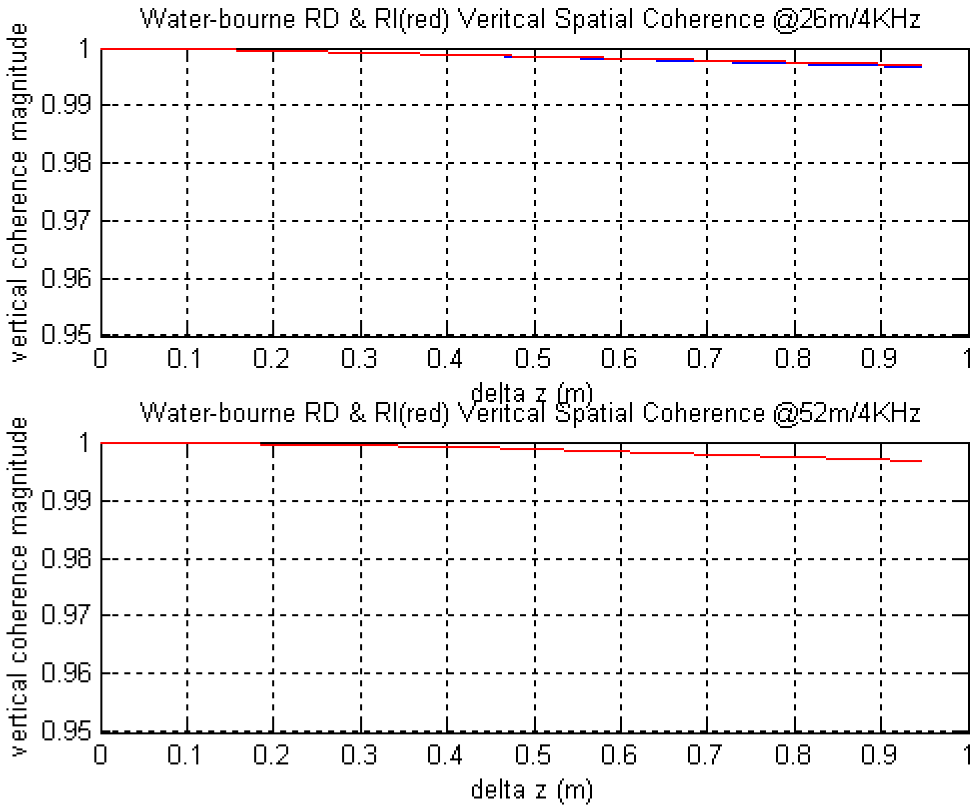




Range-Dependent, Single Sinusoid, Vertical Correlation



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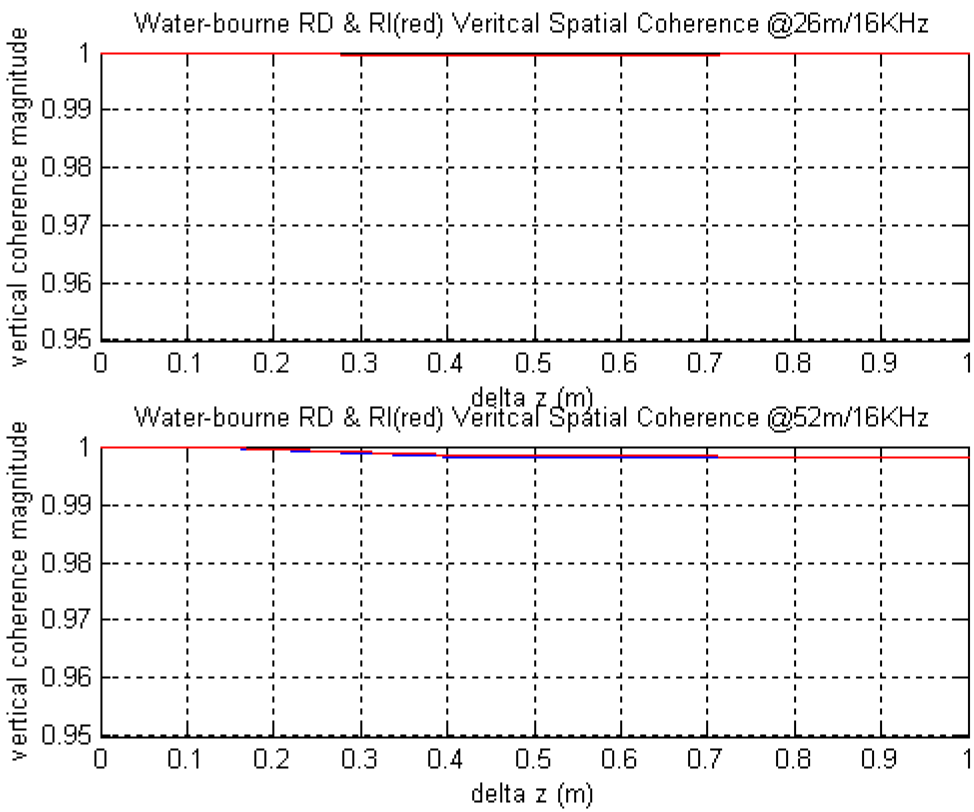
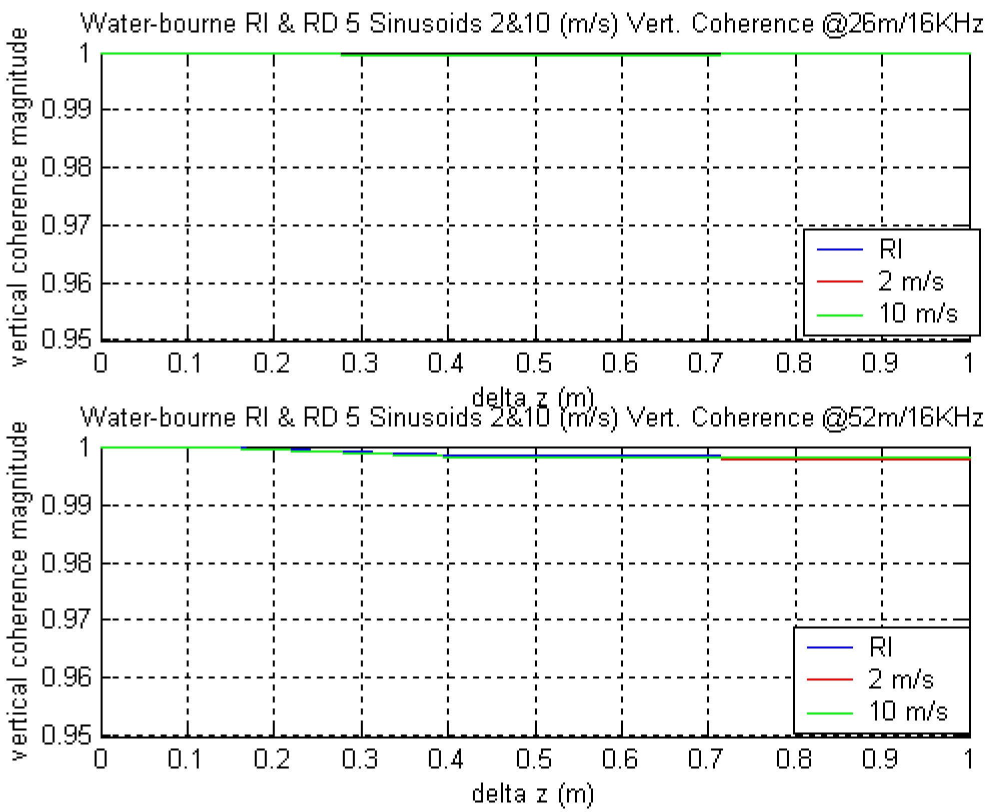


Range-Dependent, Multiple Sinusoids, Vertical Correlation



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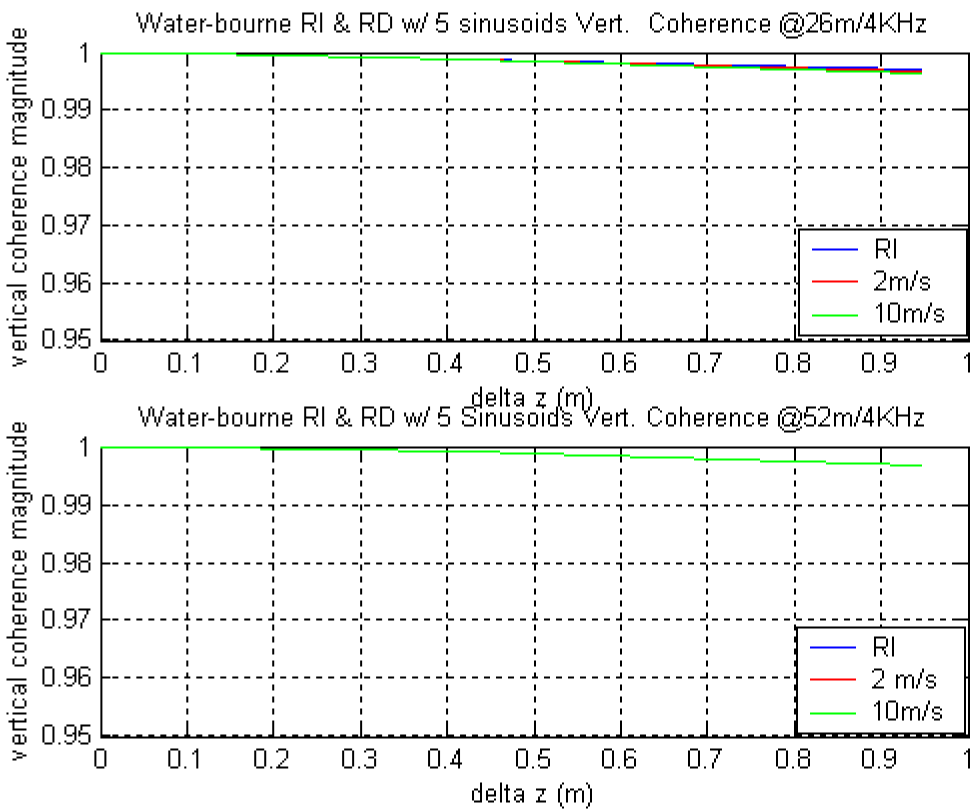

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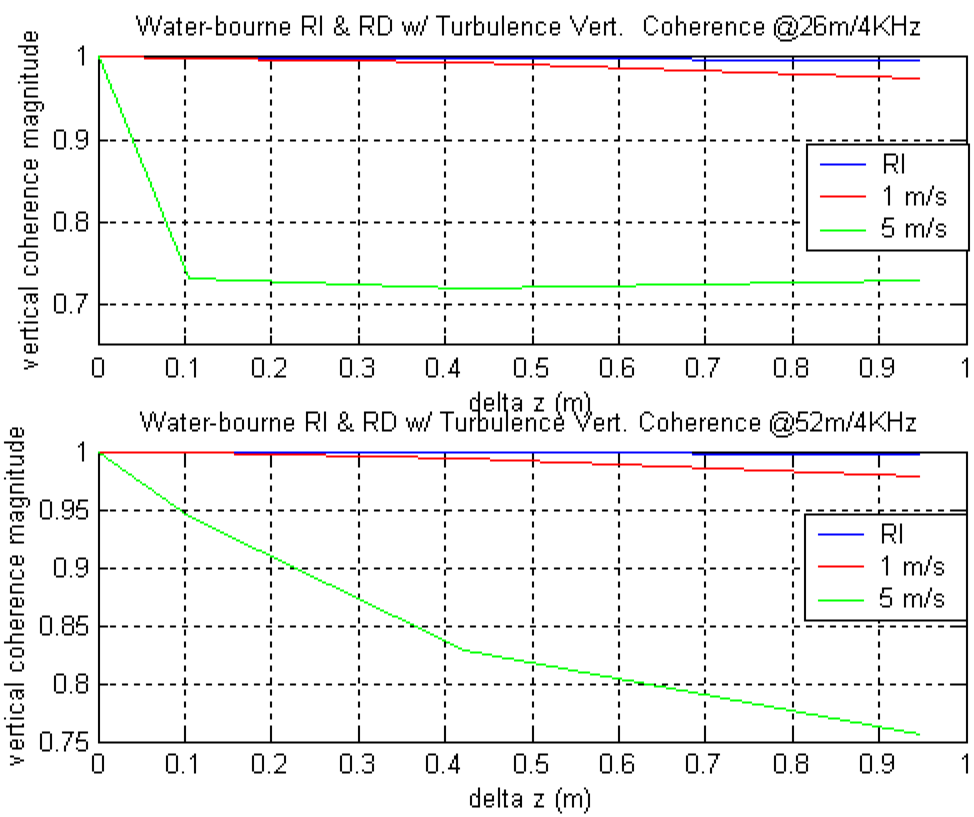

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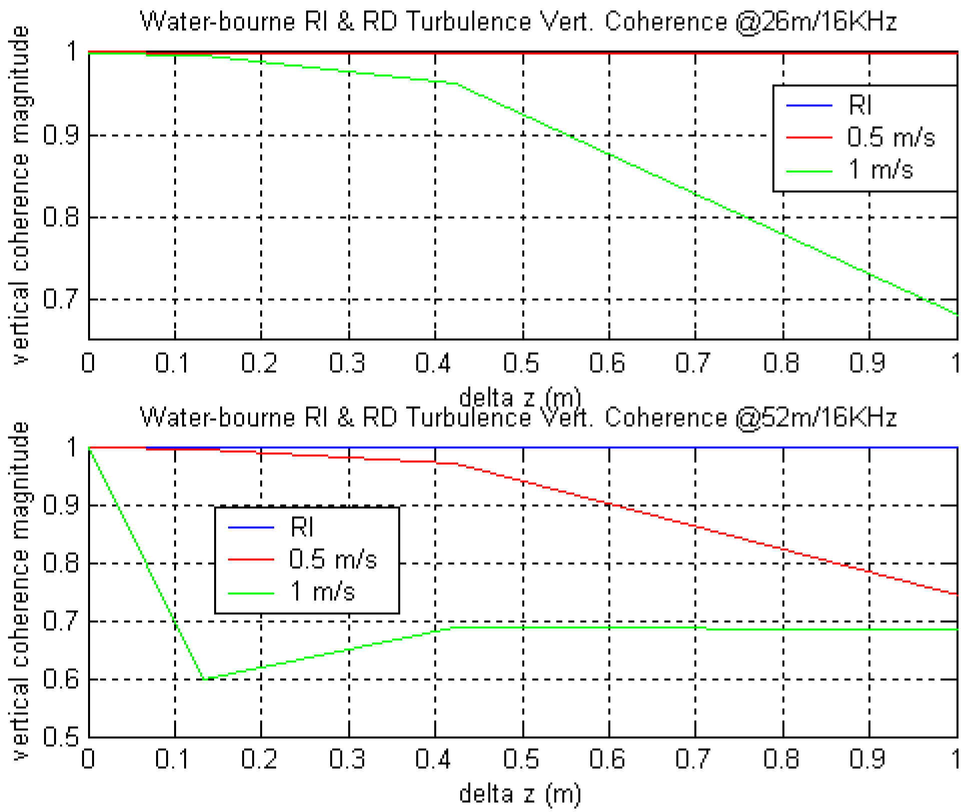

Summary

- Internal wave scale perturbations do not seem to impact vertical correlation of direct path propagation. Small scale turbulent structure appears to be necessary.
- Onset of decorrelation appears rather rapidly with increasing magnitude of turbulent fluctuations. The magnitude of the fluctuations needed for the onset also appears to be frequency dependent.
- This suggests magnitude scale of turbulent volume fluctuations may be estimated by examining onset of significant vertical decorrelation as a function of frequency.
- Future work will incorporate more realistic models of ocean volume turbulence and effects on sound speed. Model results will also be compared with measured ECS data.